

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, TOSHIHIRO TAKESUE, a citizen of Japan residing at Tokyo, Japan have invented certain new and useful improvements in

IMAGE FORMING APPARATUS AND COMPUTER-READABLE
STORAGE MEDIUM

of which the following is a specification:-

BACKGROUND OF THE INVENTION

This application claims the benefit of a Japanese Patent Application No.2000-337941 filed November 6, 2000, in the Japanese Patent Office, the disclosure of which is hereby incorporated by reference.

1. Field of the Invention

The present invention generally relates to image forming apparatuses and storage media, and more particularly to an image forming apparatus typified by a laser printer and a digital copying machine, and to a computer-readable storage medium which stores a program for causing a computer to carry out an operation of outputting an evaluation chart (or test pattern) and/or automatically correcting a phase error between a plurality of light beams.

2. Description of the Related Art

Conventionally, there are image recording apparatuses (image forming apparatuses) which employ a multi-beam system to record images at a high speed. According to the multi-beam system, the images are recorded by scanning a photoconductive body by a plurality of light beams.

In the image recording apparatus employing the multi-beam system, it is necessary to control write timings of each of the light beams at which the images

are written on the photoconductive body, so that write start positions of each of the light beams on the photoconductive body accurately match.

For example, a Japanese Laid-Open Patent
5 Application No.56-104572 proposes a beam recording apparatus which records information on a recording medium by scanning the recording medium by a plurality of light beams. A beam detector is provided outside an effective scan region of the plurality of light beams,
10 and a selected one of the plurality of light beams is controlled so that this selected light beam passes the beam detector in an ON state. A plurality of electrical modulating signals are generated to modulate the plurality of light beams, based on an output of the beam
15 detector. The modulating signals are delayed and controlled depending on the arrangements of the plurality of light beams, so that recording start positions of the plurality of light beams match on the recording medium.

20 In addition, a Japanese Laid-Open Patent Application No.57-67375 proposes a multi-beam recording apparatus which records information on a recording medium by scanning the recording medium by a plurality of light beams. A beam detector outputs a detection
25 signal when arrivals of the plurality of beams to

predetermined positions are detected. A beam selector is provided to select one of the plurality of light beams to be supplied to the beam detector. A distributor distributes the detection signal so that
5 recording start timings of the plurality of light beams are controlled depending on the distributed detection signal.

Moreover, a Japanese Laid-Open Patent Application No.61-137122 proposes a laser beam printer
10 which uses a plurality of scanning laser beams. The plurality of laser beams are arranged so as not to overlap on a photodetector, and detection signals are time-divisionally and independently detected from each of the laser beams. Signal write timings are controlled
15 depending on a correspondence of the detection signals and the laser beams.

Furthermore, a Japanese Laid-Open Patent Application No.4-35453 proposes an image forming apparatus including a plurality of light sources, a
20 photoconductive body which is irradiated by a plurality of parallel light beams emitted from the light sources and deflected to scan the photoconductive body, light sensors disposed outside a light scan region on a main scan start side of the photoconductive body, and a pixel
25 clock generating circuit for generating a pixel clock

synchronized to synchronization detection signals which are generated by detecting the light beams by the light sensors. The number of light sensors is equal to the number of light sources. In addition, the light sources and the light sensors are respectively arranged at
5 predetermined angles to a surface which is scanned by the light beams. The light sensors detect the corresponding light beams, so as to generate the synchronization detection signals.

10 The beam recording apparatus proposed in the Japanese Laid-Open Patent Application No.56-104572 is applied to cases such as when a semiconductor laser array is used as the light source and the distance between two light beams in the main scan direction on
15 the photoconductive body, that is, the recording medium, is known. Only one specific light beam is detected by the beam detector, and the modulation signal for modulating this one specific light beam is generated based on the output of the beam detector. The output of
20 the beam detector is delayed by a time corresponding to the distance between the two light beams, so as to generate a modulating signal for modulating another light beam. The write timings of all of the light beams are controlled in this manner.

25 For this reason, each light emitting position

of the semiconductor laser array is positioned extremely accurately during the production process of the beam recording apparatus. However, due to inconsistencies introduced by processing errors and assembling errors of optical parts from the light source to the photoconductive body, a slight error is introduced in the optical magnification from the light source to the photoconductive body, and it is difficult to accurately match the write positions of the plurality of light beams.

On the other hand, in the multi-beam recording apparatus proposed in the Japanese Laid-Open Patent Application No.57-67375, the laser beam printer proposed in the Japanese Laid-Open Patent Application No.61-137122 and the image forming apparatus proposed in the Japanese Laid-Open Patent Application No.4-35453, a synchronization detection signal is obtained independently for each light beam, so that it is possible to more accurately control the phase of each of the light beams. In addition, even in a case where a plurality of semiconductor lasers, including laser diodes, are used as the light source, it is possible to control the write timings of each of the light beams relatively accurately.

But normally, in the multi-beam system image

recording apparatus, when the semiconductor laser is used as the light source, each of the light beams are in many cases set so as to have predetermined intervals in the main scan direction in order to obtain predetermined beam intervals in the sub scan direction. Further, when a plurality of semiconductor lasers are used as the light source, each of the light beams are in many cases set so as to have predetermined intervals in the main scan direction so that the plurality of light beams independently reach the photodetector without overlap.

In addition, if a light intensity distribution of the light beam is inconsistent, it is impossible to obtain an accurate phase synchronizing signal. Moreover, if a difference exists in the wavelengths of the light beams, a magnification error is generated due to chromatic aberration of a scanning optical system which is formed by a $f\theta$ lens and the like.

In such cases, even if an accurate synchronization detection signal is obtained, a phase error, that is, a phase synchronization error, is generated among the light beams due to the magnification error. This phase error becomes larger towards a horizontal scanning end portion from a horizontal scanning start portion.

Furthermore, in the multi-beam system image

recording apparatus (image forming apparatus), it is necessary to control the mount of light for each of the light beams so that output images based on each of the light beams become uniform. Normally, the amount of light is controlled for each of the light beams, based on an output of a photodiode which is provided inside a package of the semiconductor laser and detects a rearward output of the semiconductor laser. However, when using the plurality of light beams, even if the amount of light of each light beam is controlled at the light source portion including the semiconductor laser, the amount of light at the time of the exposure on the photoconductive body cannot necessarily be controlled to become uniform among each of the light beams because an optical path is different for each of the light beams. Moreover, if beam spot diameters at the time of the exposure on the photoconductive body are inconsistent, the images written by each of the light beams become inconsistent even if the amount of light are the same for each of the light beams.

In order to detect the inconsistencies of the images written by the plurality of light beams, a Japanese Laid-Open Patent Application No.11-170597 proposes an image forming apparatus which prints a dot test pattern.

However, the image forming apparatus proposed in the Japanese Laid-Open Patent Application No.11-170597 prints the dot test pattern by dots, such as 2 x 2 dots, having the same phase in the main scan direction.

5 For this reason, although it is possible to detect a pitch error in the sub scan direction, there is a problem in that it is impossible to detect an error in the main scan direction.

10 SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a novel and useful image forming apparatus and computer-readable storage medium, in which the problems described above are eliminated.

15 Another and more specific object of the present invention is to provide an image forming apparatus and a computer-readable storage medium which is capable of outputting an evaluation chart (or a test pattern) which may be used to simply detect with a high
20 sensitivity a phase error of a plurality of light beams in a main scan direction in an image forming region.

Still another specific object of the present invention is to provide an image forming apparatus and a computer-readable storage medium which is capable of
25 automatically detecting a phase error of a plurality of

light beams and automatically correcting the phase error of the plurality of light beams.

A further object of the present invention is to provide an image forming apparatus comprising a light source portion emitting a plurality of light beams; a photoconductive body having an image forming surface; a deflecting unit deflecting the plurality of light beams from the light source portion to simultaneously scan the image forming surface of the photoconductive body; and a controller controlling the plurality of light beams to form an evaluation chart on the image forming surface of the photoconductive body, where the evaluation chart includes first patterns and second patterns, in the first pattern, with respect to a row of dots formed in a main scan direction by a predetermined light beam, a row of dots formed by a next light beam is shifted in the main scan direction, in the second pattern, with respect to the row of dots formed in the main scan direction by the predetermined light beam, the row of dots formed by the next light beam is shifted in the main scan direction but in a direction opposite to a shift direction of the first pattern, and the evaluation chart includes a first pattern group which is formed by the first patterns which are repeated in a sub scan direction with a period that is an integer multiple of a

total number of the plurality of light beams and are also repeated in the main scan direction at predetermined intervals, and a second pattern group which is formed by the second patterns which are

5 repeated in the sub scan direction with a period that is an integer multiple of the total number of light beams and are also repeated in the main scan direction at predetermined intervals. According to the image forming apparatus of the present invention, it is possible to

10 simply detect with a high sensitivity a phase error of the plurality of light beams in the main scan direction within the image forming region, based on the evaluation chart.

The image forming apparatus may further

15 comprise an output section printing the evaluation chart on the image forming surface of the photoconductive body onto a recording medium. In this case, the phase error can be visually detected from the evaluation chart printed on the recording medium.

20 In the image forming apparatus, the output section may print the evaluation chart such that, of the plurality of light beams B_1, B_2, \dots, B_m , where $B_m \geq 2$, the first and second pattern groups formed by the light beams B_1 and B_2 , the first and second pattern groups

25 formed by the light beams B_2 and B_3, \dots , the first and

second pattern groups formed by the light beams $B(m-1)$ and B_m , and the first and second pattern groups formed by the light beams B_m and B_1 are printed on a single recording medium. In this case, it is possible to
5 efficiently detect the phase error without being greatly affected by variation factors of the image forming apparatus.

In the image forming apparatus, corresponding first and second pattern groups may be arranged adjacent
10 to each other on the evaluation chart. In this case, it is possible to efficiently detect the phase error without being greatly affected by variation factors of the image forming apparatus.

In the image forming apparatus, each first
15 pattern group may have a corresponding second pattern group arranged adjacent thereto in both the main scan direction and the sub scan direction. In this case, it is possible to accurately detect the phase error of the light beams.

20 In the image forming apparatus, the controller may variably control a number of dots of the row of dots of each of the plurality of light beams when forming the evaluation chart. In this case, it is possible to simply detect the phase error of the light beams even if
25 the apparatus or the resolution differs.

In the image forming apparatus, the controller may variably control a distance in the main scan direction between the row of dots formed by the predetermined light beam and the row of dots formed by the next light beam when forming the evaluation chart. In this case, it is possible to simply detect the phase error of the light beams even if the apparatus or the resolution differs.

In the image forming apparatus, the controller may variably control conditions related to forming the dots when forming the evaluation chart. In this case, it is possible to efficiently detect the phase error of the light beams without being greatly affected by the variation factors of the image forming apparatus.

In the image forming apparatus, the controller may control the plurality of light beams to form an evaluation chart having a pattern group of one of the plurality of light beams with a phase which is shifted in advance in the main scan direction, with respect to each of the first pattern group and the second pattern group. In this case, it is possible to simply detect the phase correcting amount corresponding to the phase error of the light beams, and thus efficiently detect the phase error of the light beams.

The image forming apparatus may further

comprise phase correcting amount setting means for setting a phase correcting amount in the main scan direction. In this case, it is possible to simply detect the phase correcting amount corresponding to the
5 phase error of the light beams, and thus efficiently detect the phase error of the light beams.

Another object of the present invention is to provide an image forming apparatus comprising a light source portion emitting a plurality of light beams; a
10 photoconductive body having an image forming surface; a deflecting unit deflecting the plurality of light beams from the light source portion to simultaneously scan the image forming surface of the photoconductive body; and a controller controlling the plurality of light beams to
15 form an evaluation chart on the image forming surface of the photoconductive body, where the evaluation chart includes first patterns and second patterns, in the first pattern, with respect to a row of dots formed in a main scan direction by a predetermined light beam, a row
20 of dots formed by a next light beam is shifted in the main scan direction, in the second pattern, with respect to the row of dots formed in the main scan direction by the predetermined light beam, the row of dots formed by the next light beam is shifted in the main scan
25 direction but in a direction opposite to a shift

direction of the first pattern, and the evaluation chart includes a first pattern group which is formed by the first patterns which are repeated in a sub scan direction with a period that is an integer multiple of a total number of the plurality of light beams, and a second pattern group which is formed by the second patterns which are repeated in the sub scan direction with a period that is an integer multiple of the total number of light beams. According to the image forming apparatus of the present invention, it is possible to simply detect with a high accuracy the phase error of the plurality of light beams in the main scan direction within the image forming region.

The image forming apparatus may further comprise an output section printing the evaluation chart on the image forming surface of the photoconductive body onto a recording medium. In this case, the phase error can be visually detected from the evaluation chart printed on the recording medium.

In the image forming apparatus, the first and second pattern groups arranged in the sub scan direction in the evaluation chart may be disposed in a scan start side of a scan range of the deflecting unit. In this case, it is possible to simply detect the phase error of the light beams without being greatly affected by

variation factors such as a polygon mirror included in the deflecting unit.

In the image forming apparatus, the first and second pattern groups arranged in the sub scan direction
5 in the evaluation chart may be disposed in approximately a central portion of a scan range of the deflecting unit. In this case, it is possible to simply detect the phase error of the light beams without being greatly affected by variation factors such as a distortion introduced by
10 an optical system.

In the image forming apparatus, the controller may variably control a number of dots of the row of dots of each of the plurality of light beams when forming the evaluation chart. In this case, it is possible to
15 simply detect the phase error of the light beams even if the apparatus or the resolution differs.

In the image forming apparatus, the controller may variably control a distance in the main scan direction between the row of dots formed by the
20 predetermined light beam and the row of dots formed by the next light beam when forming the evaluation chart. In this case, it is possible to simply detect the phase error of the light beams even if the apparatus or the resolution differs.

25 In the image forming apparatus, the controller

may variably control conditions related to forming the dots when forming the evaluation chart. In this case, it is possible to efficiently detect the phase error of the light beams without being greatly affected by the
5 variation factors of the image forming apparatus.

In the image forming apparatus, the controller may control the plurality of light beams to form an evaluation chart having a pattern group of one of the plurality of light beams with a phase which is shifted
10 in advance in the main scan direction, with respect to each of the first pattern group and the second pattern group. In this case, it is possible to simply detect the phase correcting amount corresponding to the phase error of the light beams, and thus efficiently detect
15 the phase error of the light beams.

The image forming apparatus may further comprise phase correcting amount setting means for setting a phase correcting amount in the main scan direction. In this case, it is possible to simply
20 detect the phase correcting amount corresponding to the phase error of the light beams, and thus efficiently detect the phase error of the light beams.

Still another object of the present invention is to provide an image forming apparatus comprising
25 pattern group generating means for generating on an

image forming surface of a photoconductive body an evaluation chart having a pattern group of one of a plurality of light beams with a phase which is shifted in advance in a main scan direction, with respect to
5 each of a first pattern group and a second pattern group; tone measuring means for measuring a tone of the pattern group in the evaluation chart; and phase correcting amount setting means for setting a phase correcting amount in the main scan direction, based on
10 the tone measured by the tone measuring means.

According to the image forming apparatus of the present invention, it is possible to automatically detect the phase error of the light beams and obtain the phase correcting amount, without the need to output the
15 evaluation chart on a recording medium such as paper.

The image forming apparatus may further comprise phase synchronizing signal generating means for generating phase synchronizing signals of the plurality of light beams, based on the phase correcting amount set
20 by the phase correcting amount setting means. In this case, it is possible to automatically adjust the phase error of the light beams.

A further object of the present invention is to provide an image forming apparatus comprising a
25 pattern group generator generating on an image forming

surface of a photoconductive body an evaluation chart having a pattern group of one of a plurality of light beams with a phase which is shifted in advance in a main scan direction, with respect to each of a first pattern group and a second pattern group; a tone sensor measuring a tone of the pattern group in the evaluation chart; and a phase correcting amount setting circuit setting a phase correcting amount in the main scan direction, based on the tone measured by the tone sensor.

10 According to the image forming apparatus of the present invention, it is possible to automatically detect the phase error of the light beams and obtain the phase correcting amount, without the need to output the evaluation chart on a recording medium such as paper.

15 A further object of the present invention is to provide a computer-readable storage medium which stores a program for causing a computer to carry out an imaging process comprising the procedures of causing the computer to deflect a plurality of light beams to

20 simultaneously scan an image forming surface of a photoconductive body; and causing the computer to control the plurality of light beams to form an evaluation chart on the image forming surface of the photoconductive body, where the evaluation chart

25 includes first patterns and second patterns, in the

first pattern, with respect to a row of dots formed in a main scan direction by a predetermined light beam, a row of dots formed by a next light beam is shifted in the main scan direction, in the second pattern, with respect to the row of dots formed in the main scan direction by the predetermined light beam, the row of dots formed by the next light beam is shifted in the main scan direction but in a direction opposite to a shift direction of the first pattern, and the evaluation chart includes a first pattern group which is formed by the first patterns which are repeated in a sub scan direction with a period that is an integer multiple of a total number of the plurality of light beams and are also repeated in the main scan direction at predetermined intervals, and a second pattern group which is formed by the second patterns which are repeated in the sub scan direction with a period that is an integer multiple of the total number of light beams and are also repeated in the main scan direction at predetermined intervals. According to the computer-readable storage medium of the present invention, it is possible to simply detect with a high sensitivity a phase error of the plurality of light beams in the main scan direction within the image forming region, based on the evaluation chart.

Another object of the present invention is to provide a computer-readable storage medium which stores a program for causing a computer to carry out an imaging process comprising the procedures of causing the

5 computer to deflect a plurality of light beams to simultaneously scan an image forming surface of a photoconductive body; and causing the computer to control the plurality of light beams to form an evaluation chart on the image forming surface of the

10 photoconductive body, where the evaluation chart includes first patterns and second patterns, in the first pattern, with respect to a row of dots formed in a main scan direction by a predetermined light beam, a row of dots formed by a next light beam is shifted in the

15 main scan direction, in the second pattern, with respect to the row of dots formed in the main scan direction by the predetermined light beam, the row of dots formed by the next light beam is shifted in the main scan direction but in a direction opposite to a shift

20 direction of the first pattern, and the evaluation chart includes a first pattern group which is formed by the first patterns which are repeated in a sub scan direction with a period that is an integer multiple of a total number of the plurality of light beams, and a

25 second pattern group which is formed by the second

patterns which are repeated in the sub scan direction with a period that is an integer multiple of the total number of light beams. According to the computer-readable storage medium of the present invention, it is possible to simply detect with a high sensitivity a phase error of the plurality of light beams in the main scan direction within the image forming region, based on the evaluation chart.

Still another object of the present invention is to provide a computer-readable storage medium which stores a program for causing a computer to carry out an imaging process comprising the procedures of causing the computer to generate on an image forming surface of a photoconductive body an evaluation chart having a pattern group of one of a plurality of light beams with a phase which is shifted in advance in a main scan direction, with respect to each of a first pattern group and a second pattern group; causing the computer to measure a tone of the pattern group in the evaluation chart; and causing the computer to set a phase correcting amount in the main scan direction, based on the measured tone. According to the computer-readable storage medium of the present invention, it is possible to automatically detect the phase error of the light beams and obtain the phase correcting amount, without

the need to output the evaluation chart on a recording medium such as paper.

Other objects and further features of the present invention will be apparent from the following
5 detailed description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross sectional view generally
10 showing an image forming apparatus according to the present invention;

FIG. 2 is a diagram showing a general structure of a laser optical system unit;

FIGS. 3A and 3B are diagrams for explaining an
15 evaluation chart used in a first embodiment;

FIG. 4 is a diagram for explaining the evaluation chart used in the first embodiment;

FIG. 5 is a diagram for explaining the evaluation chart used in the first embodiment;

20 FIG. 6A and 6B are diagrams for explaining the evaluation chart used in the first embodiment;

FIG. 7A and 7B are diagrams for explaining the evaluation chart used in the first embodiment;

25 FIG. 8A and 8B are diagrams for explaining the evaluation chart used in the first embodiment;

FIG. 9 is a diagram for explaining the evaluation chart used in the first embodiment;

FIGS. 10A and 10B are diagrams for explaining a phase error of light beams in a main scan direction;

5 FIGS. 11A and 11B are diagrams for explaining the phase error of the light beams in the main scan direction;

 FIGS. 12A and 12B are diagrams for explaining the phase error of the light beams in the main scan
10 direction;

 FIGS. 13A and 13B are diagrams for explaining the phase error of the light beams in the main scan direction;

 FIG. 14 is a diagram for explaining another
15 evaluation chart used in the first embodiment;

 FIG. 15 is a diagram for explaining an evaluation chart used in a second embodiment;

 FIG. 16 is a diagram for explaining the evaluation chart used in the second embodiment;

20 FIG. 17 is a diagram for explaining the evaluation chart used in the second embodiment;

 FIG. 18 is a diagram for explaining a dot position error caused by irregular rotation of a polygon motor;

25 FIGS. 19A and 19B are diagrams for explaining

a pattern for a case where the number of semiconductor lasers is two and the number of rows of dots formed by one light beam in a main scan direction is one;

FIGS. 20A and 20B are diagrams for explaining
5 a pattern for a case where the number of semiconductor lasers is four and the number of rows of dots formed by one light beam in the main scan direction is four;

FIGS. 21A and 21B are diagrams for explaining
first and second patterns A and B for a case where, with
10 respect to a row of dots formed by a first light beam B1, a row of dots formed by a second light beam B2 has a distance deviation Δ in the main scan direction;

FIGS. 22A and 22B are diagrams for explaining
a phase error of the light beams in the main scan
15 direction;

FIG. 23 is a system block diagram showing a structure of a circuit for generating the first pattern A shown in FIG. 21A;

FIGS. 24A and 24B are timing charts for
20 explaining an operation of the circuit shown in FIG. 23;

FIG. 25 is a flow chart for explaining a bias setting process;

FIG. 26 is a diagram for explaining an image formation by four light beams B1, B2, B3 and B3 which
25 are aligned without an error;

FIG. 27 is a system block diagram showing a circuit for generating horizontal synchronizing signals S1, S2, S3 and S4 which are used to synchronize the phases of the light beams B1, B2, B3 and B4 when an optical system of the four light beams B1, B2, B3 and B4 is used;

FIG. 28 is a diagram for explaining a case where the phase error of the light beams exists;

FIG. 29 is a timing chart for explaining an adjustment of time intervals t_{12} , t_{23} , and t_{34} of the horizontal synchronizing signals S1, S2, S3 and S4;

FIG. 30 is a timing chart for explaining a dot shift caused by the timing adjustment of the horizontal synchronizing signal;

FIG. 31 is a flow chart for explaining a process of correcting the phase error of the light beams using a delay setting circuit shown in FIG. 27;

FIG. 32 is a system block diagram showing a structure of a phase synchronizing signal generating means shown in FIG. 27;

FIGS. 33A and 33B are diagrams for explaining the first pattern A and the second pattern B for a case where the phase of the light beam B2 in the main scan direction is shifted in advance;

FIGS. 34A and 34B are diagrams for explaining

the first pattern A and the second pattern B for the case where the phase of the light beam B2 in the main scan direction is shifted in advance;

FIGS. 35A and 35B are diagrams for explaining
5 the first pattern A and the second pattern B for the case where the phase of the light beam B2 in the main scan direction is shifted in advance;

FIG. 36 is a diagram showing another evaluation chart used in the second embodiment;

10 FIG. 37 is a flow chart for explaining a process of manually adjusting a phase error;

FIG. 38 is a system block diagram showing a structure of an image forming apparatus which is provided with a function of automatically correcting or
15 adjusting the phase error;

FIG. 39 is a diagram for explaining setting of a tone measuring means which measures a tone of a pattern group on a photoconductive body;

FIG. 40 is a diagram for explaining the
20 pattern group formed on the photoconductive body;

FIG. 41 is a flow chart for explaining an automatic adjusting or correcting process for adjusting or correcting the phase error of the light beams in the image forming apparatus shown in FIGS. 38 and 39; and

25 FIG. 42 is a system block diagram showing a

hardware structure of a video controller.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Various embodiments of an image forming
5 apparatus according to the present invention and a
computer-readable storage medium according to the
present invention, will now be described with reference
to the drawings.

FIG. 1 is a cross sectional view generally
10 showing an image forming apparatus according to the
present invention. In the image forming apparatus shown
in FIG. 1, a paper on which an image is to be formed, is
set on a main tray 101 or a manual feed tray 102. Of
course, any recording media or sheet other than paper
15 may be used. A transport of this paper from the tray
101 or 102 is started by paper supply rollers 103.

Prior to the paper transport by the paper
supply rollers 103, a photoconductive body
(photoconductive drum) 66 rotates, and a surface of the
20 photoconductive body 66 is cleaned by a cleaning blade
105. Then, the surface of the photoconductive body 66
is uniformly charged by a charge roller 106. A laser
beam which is modulated according to an image signal
from a video controller 71 received via a laser diode
25 (LD) driving circuit 72 is emitted from a laser optical

system unit 107, and this laser beam exposes the charged surface of the photoconductive body 66. The exposed surface of the photoconductive body 66 is developed by a developing roller 108 and applied with a toner. At the same time, the paper is supplied by the paper supply rollers 103 at an appropriate timing.

The paper supplied from the paper supply rollers 103 is transported in a state pinched between the photoconductive body 66 and a transfer roller 109, and at the same time, a toner image is transferred onto the paper. Residual toner on the photoconductive body 66 is removed by the cleaning blade 105.

A toner density sensor 110 is provided in front of the cleaning blade 105, and it is possible to measure a density of the toner image formed on the photoconductive body 66 by the toner density sensor 110. In addition, the paper having the toner image transferred thereon is transported to a fixing unit 111 via a transport path, and the toner image is fixed on the paper by the fixing unit 111.

The printed paper having the fixed image thereon is ejected, face down, via ejection rollers 112, so that the surface of the printed paper having the fixed image faces down. When a plurality of printed papers are ejected, the papers are ejected in the order

of pages.

The video controller 71 and the laser diode driving circuit 72 are connected to the laser optical system unit 107. The video controller 71 controls image
5 signals from a personal computer, a work station and the like, and generates an evaluation charge (test pattern) signal which is held therein.

A high-voltage bias is applied to the developing roller 108 by a bias circuit 114. By
10 controlling the bias by the bias circuit 114, it is possible to control the total tone of the image.

FIG. 2 is a diagram showing a general structure of the laser optical system unit 107. In the laser optical system unit 107 shown in FIG. 2, two
15 mirrors 121 and 122 are used as shown in FIG. 1 in order to reduce the size of the laser optical system unit 107. However, the illustration of the mirrors 121 and 122 is omitted in FIG. 2 for the sake of convenience in order to simplify the drawing.

20 As shown in FIG. 2, the laser optical system unit 107 includes a light source portion 61, a cylindrical lens 62, a polygon mirror 63 which is used as a deflecting means, a $f\theta$ lens 64, and a toroidal lens 65.

25 In the case shown in FIG. 2, the light source

portion 61 includes four semiconductor lasers 85, 86, 87 and 88, four collimator lenses 81, 82, 83 and 84, and a prism 17. Four light beams from the four semiconductor lasers 85, 86, 87 and 88 are formed into approximately parallel rays by the corresponding collimator lenses 81, 82, 83 and 84, and the four light beams are thereafter aligned approximately to one vertical column by the prism 17.

Next, a description will be given of an operation of the image forming apparatus having the structure described above. In the light source portion 61, the four light beams from the four semiconductor lasers 85, 86, 87 and 88 are converted into the approximately parallel rays by the corresponding collimator lenses 81, 82, 83 and 84, and the four light beams are thereafter aligned approximately to one vertical column by the prism 17, as described above. The four aligned light beams pass through the cylindrical lens 62 and reach the polygon mirror 63.

The polygon mirror 63 rotates in a direction R in FIG. 2, and deflects the four incoming light beams in a horizontal direction, that is, in a main scan direction.

The four light beams deflected in the main scan direction passes through the $f\theta$ lens 64 and the

toroidal lens 65, and scan the photoconductive body 66 at the same speed.

In the case shown in FIG. 1, the mirrors 121 and 122 are provided in the optical path at an intermediate portion of the optical system.

In FIG. 2, a horizontal synchronizing sensor 69 is provided at a scan starting end of the light beam in the main scan direction. An output of the horizontal synchronizing sensor 69 is used to achieve synchronization in the main scan direction. The horizontal synchronizing sensor 69 is arranged at the scan starting end outside an image forming region 66a. The photoconductive body 66 rotates in a direction Q shown in FIG. 2, and a latent image formed in the image forming region on the photoconductive body 66 is visualized by the developing roller 108.

The image forming apparatus is also provided with an operation panel 74 as shown in FIG. 2. The operation panel 74 is used to display an operating state of the image forming apparatus, and is used to set the operation mode and to set data during operation.

The data to be printed on the paper is transferred from an interface 75 to the video controller (video control circuit) 71 which converts the data into a bit map data. The bit map data

from the video controller 71 is supplied to the laser diode driving circuit 72 which modulates the four semiconductor lasers 85, 86, 87 and 88 by the bit map data in synchronism with the horizontal synchronizing
5 signal received from a phase synchronizing signal generating means 70.

First Embodiment:

In a first embodiment of the image forming apparatus according to the present invention, the
10 plurality of light beams emitted from the light source portion 61 are deflected by the polygon mirror 63 which forms the deflecting means and simultaneously scan the photoconductive body 66 in the main scan direction. This image forming apparatus forms a digital copying
15 machine, a printer and the like, and is characterized in that an evaluation chart which will be described hereunder is output. The evaluation chart includes first patterns and second patterns. In the first pattern, with respect to a row of dots formed in the
20 main scan direction by one predetermined light beam, a row of dots formed by the next one light beam is shifted in the main scan direction. In the second pattern, with respect to the row of dots formed in the main scan direction by one predetermined light beam, a row of dots
25 formed by the next one light beam is shifted in the main

scan direction but in a direction opposite to the shift direction of the first pattern. The evaluation chart actually includes a first pattern group which is formed by the first patterns which are repeated in the sub scan direction with a period that is an integer multiple of the number of light beams and are also repeated in the main scan direction at predetermined intervals, and a second pattern group which is formed by the second patterns which are repeated in the sub scan direction with a period that is an integer multiple of the number of light beams and are also repeated in the main scan direction at predetermined intervals.

FIGS. 3A, 3B, 4, 5, 6A, 6B, 7A, 7B, 8A, 8B and 9 are diagrams for explaining the evaluation chart used in this first embodiment. In FIGS. 3A through 9, it is assumed for the sake of convenience that the number of semiconductor lasers is four as shown in FIG. 2, and light beams B1, B2, B3 and B4 are respectively emitted from the four semiconductor lasers 85, 86, 87 and 88.

FIG. 3A is a diagram for explaining a first pattern A, and FIG. 3B is a diagram for explaining a second pattern B. In FIGS. 3A and 3B, each dot is indicated by a circular mark.

The first pattern A includes image patterns A1 and A2, as shown in FIG. 3A. In the image pattern A1, a

row of dots formed on the photoconductive body 66 in the main scan direction by one predetermined light beam, that is, the first light beam B1 from the semiconductor laser 85, for example, is repeated in the sub scan direction with a period which is an integer multiple (integer is one in the case shown in FIG. 3A) of a number nb of light beams used. In this case, nb = 4. In addition, in the image pattern A2, a row of dots formed on the photoconductive body 66 in the main scan direction by the next one light beam B2 from the semiconductor laser 86 is repeated in the sub scan direction with a period which is an integer multiple (integer is one in the case shown in FIG. 3A) of the number nb (= 4) of light beams used.

15 The second pattern B is a mirror image of the first pattern A taken along the main scan direction, as shown in FIG. 3B. In other words, in the case of the second pattern B, with respect to the row of dots formed by one predetermined light beam in the main scan direction, the row of dots formed by the next light beam in the main scan direction is shifted in a direction opposite to the shift direction of the first pattern A.

20 The first pattern A is repeated in the main scan direction and the sub scan direction to form a first pattern group P12a, and the second pattern B is

repeated in the main scan direction and the sub scan direction to form a second pattern group P12b, as shown in FIGS. 3A and 3B.

FIGS. 3A and 3B show the case where the
5 optical system used emits the four light beams, that is, the top light beam B1 through the bottom light beam B4, and the four light beams B1 through B4 simultaneously scan in the main scan direction. In FIG. 3A, the light beam B1 exposes the row of dots at phases t1 and t2 in
10 the horizontal direction, as indicated by the circular marks, and the image pattern A1 is exposed as a result. By this exposure of the image pattern A1, the toner image is adhered on the photoconductive body 66 in an approximately oval region surrounding the image pattern
15 A1. Similarly, the image pattern A2 is exposed by the light beam B2, and the toner image is adhered on the photoconductive body 66 in an approximately oval region surrounding the image pattern A2. The first pattern A is formed by these image patterns A1 and A2.

20 As shown in FIG. 3B, the second pattern B is the mirror image of the first pattern A shown in FIG. 3A taken along the main scan direction. Hence, the toner images are also adhered on the photoconductive body 66 in approximately oval regions respectively surrounding
25 the image patterns forming the second pattern B.

FIG. 4 shows the first pattern group P12a which is formed by repeating the first pattern A shown in FIG. 3A in both the main scan direction and the sub scan direction. Similarly, FIG. 5 shows the second pattern group P12b which is formed by repeating the second pattern B shown in FIG. 3B in both the main scan direction and the sub scan direction.

Therefore, in FIGS. 3A and 3B, the first and second pattern groups P12a and P12b are formed by the light beams B1 and B2.

Similarly, first and second pattern groups P23a and P23b respectively shown in FIGS. 6A and 6B are formed by the light beams B2 and B3. In other words, the first pattern group P23a is formed by repeating the first pattern A (A2, A3) in both the main scan direction and the sub scan direction in FIG. 6A, and the second pattern group P23b is formed by repeating the second pattern B in both the main scan direction and the sub scan direction in FIG. 6B.

In addition, first and second pattern groups P34aa and P34b respectively shown in FIGS. 7A and 7B are formed by the light beams B3 and B4. In other words, the first pattern group P34a is formed by repeating the first pattern A (A3, A4) in both the main scan direction and the sub scan direction in FIG. 7A, and the second

pattern group P34b is formed by repeating the second pattern B in both the main scan direction and the sub scan direction in FIG. 7B.

Furthermore, first and second pattern groups
5 P41a and P41b respectively shown in FIGS. 8A and 8B are formed by the light beams B4 and B1. In other words, the first pattern group P41a is formed by repeating the first pattern A (A4, A1) in both the main scan direction and the sub scan direction in FIG. 8A, and the second
10 pattern group P41b is formed by repeating the second pattern B in both the main scan direction and the sub scan direction in FIG. 8B.

FIG. 9 shows the evaluation chart which includes the first pattern groups P12a, P23a, P34a and
15 P41a and the second pattern groups P12b, P23b, P34b and P41b which are printed on the paper. In FIG. 9, a paper transport direction (sub scan direction) is indicated by an arrow C. In the evaluation chart shown in FIG. 9, a print region of the second pattern group P12b is
20 provided inside a print region of the first pattern group P12a, so that the first pattern group P12a is printed in the print region of the first pattern group P12a and the second pattern group P12b is printed in the print region of the second pattern group P12b inside the
25 print region of the first pattern group P12a. Print

regions of the first pattern groups P23a, P34a and P41a and print regions of the second pattern groups P23b, P34b and P41b are set similarly to the print regions of the first and second pattern groups P12a and P12b described above.

If a phase error exists in the main scan direction between the light beams B1 and B2, for example, the print tone of the first pattern group P12a and the print tone of the second pattern group P12b become different in the evaluation chart. Hence, it is possible to detect the phase error in the main scan direction between the light beams B1 and B2 based on the print tones of the first and second pattern groups P12a and P12b printed on the evaluation chart.

FIGS. 10A and 10B are diagrams for explaining the phase error of the light beams B1 and B2 in the main scan direction, respectively in correspondence with FIGS. 3A and 3B. If there is no phase error in the main scan direction between the light beams B1 and B2 as shown in FIGS. 3A and 3B, a width W12a of the toner image of the first pattern A is equal to a width W12b of the toner image of the second pattern B. Hence, the print tone of the first pattern group P12a formed by the first pattern A in this case becomes the same as the print tone of the second pattern group P12b formed by the second pattern B.

On the other hand, if the phase error in the main scan direction between the light beams B1 and B2 amounts to one-half dot (the phase of the light beam B2 is shifted by one-half dot) as shown in FIGS. 10A and 10B due to a mounting error, adjustment error or the like of the semiconductor lasers 85 and 86, the width W12a of the toner image of the first pattern A and the width W12b of the toner image of the second pattern B become different. When the phase error in the main scan direction exists between the light beams B1 and B2, the width and the area of the region where the toner is adhered becomes different between the first pattern A and the second pattern B, and results in the difference between the image tone of the first pattern group P12a and the image tone of the second pattern group P12b. The difference between the widths or the tones of the toner images can be detected as a regular and sharp width difference or tone deviation on the image patterns which should originally be a uniform half-tone image. For this reason, it is possible to detect the difference between the widths or the tones of the toner images with an extremely high sensitivity even when relying on visual detection by the human eyes.

Similarly, if the phase error in the main scan direction exists between the light beams B2 and B3 as

shown in FIGS. 11A and 11B, a width W23a of the toner image of the first pattern A and a width W23b of the toner image of the second pattern B become different. The difference between the widths W23a and W23b of the toner images can be detected as a difference in the image tones of the first and second pattern groups P23a and P23b.

In addition, if the phase error in the main scan direction exists between the light beams B3 and B4 as shown in FIGS. 12A and 12B, a width W34a of the toner image of the first pattern A and a width W34b of the toner image of the second pattern B become different. The difference between the widths W34a and W34b of the toner images can be detected as a difference in the image tones of the first and second pattern groups P34a and P34b.

Furthermore, if the phase error in the main scan direction exists between the light beams B4 and B1 as shown in FIGS. 13A and 13B, a width W41a of the toner image of the first pattern A and a width W41b of the toner image of the second pattern B become different. The difference between the widths W41a and W41b of the toner images can be detected as a difference in the image tones of the first and second pattern groups P41a and P41b.

In the case of the evaluation chart shown in FIG. 9, the image region of the second pattern group P12b is printed inside the image region of the first pattern group P12a, the image region of the second pattern group P23b is printed inside the image region of the first pattern group P23a, the image region of the second pattern group P34b is printed inside the image region of the first pattern group P34a, and the image region of the second pattern group P41b is printed inside the image region of the first pattern group P41a. Hence, the first pattern groups P12a, P23a, P34a and P41a are respectively arranged close to the corresponding second pattern groups P12b, P23b, P34b and P41b, and it is possible to easily and accurately detect visually the difference between the image tones of the first pattern group and the corresponding second pattern group. In other words, it is possible to visually detect even a slight phase error between two light beams. For example, when it is visually detected that there is a difference between the image tone of the first pattern group P12a and the image tone of the second pattern group P12b in the evaluation chart shown in FIG. 9, it can be detected that a phase error exists between the light beams B1 and B2.

FIG. 14 is a diagram for explaining another

evaluation chart used in this first embodiment. In FIG. 14, those parts which are the same as those corresponding parts in FIG. 9 are designated by the same reference numerals, and a description thereof will be omitted. In the evaluation chart shown in FIG. 14, two first pattern groups P12a, two second pattern groups P12b, two first pattern groups P23a, two second pattern groups P23b, two first pattern groups P34a, two second pattern groups P34b, two first pattern groups P41a, and two second pattern groups P41b are arranged as shown, so that each first pattern group has one corresponding second pattern group arranged adjacent thereto in both the main scan direction and the sub scan direction, and each second pattern group has one corresponding first pattern group arranged adjacent thereto in both the main scan direction and the sub scan direction. For example, the first pattern group P12a has one corresponding second pattern group P12b arranged adjacent thereto in the main scan direction (to the right or left) and one corresponding second pattern group P12b arranged adjacent thereto in the sub scan direction (below or above). Similarly, the second pattern group P12b has one corresponding first pattern group P12a arranged adjacent thereto in the main scan direction (to the left or right) and one corresponding first pattern group P12a

arranged adjacent thereto in the sub scan direction
(above or below).

When detecting the phase error between the
light beams B1 and B2 using the evaluation chart shown
5 in FIG. 14, for example, it is possible to compare the
top left first pattern group P12a and the top right
second pattern group P12b or the lower left second
pattern group P12b. For this reason, even if the
developing process introduces unevenness in the main
10 scan direction and/or in the sub scan direction, it is
possible to effectively and accurately detect the phase
error between the light beams B1 and B2.

In addition, when generating the image data of
the first and second pattern groups by hardware such as
15 the video controller 71, it is simpler to design the
circuit if the image regions of the first and second
pattern groups are independent of each other and
rectangular as shown in FIG. 14, compared to the case
where the image regions of the first and second pattern
20 groups overlap as shown in FIG. 9.

The first and second pattern groups, such as
the first and second pattern groups P12a and P12b, which
are to be mutually compared, may be printed on
independent papers. However, it is desirable that the
25 corresponding first and second pattern groups are

printed on the same paper, and adjacent to each other,
as shown in FIGS, 9 and 14, so as to facilitate the
comparison. When the corresponding first and second
pattern groups are printed on the same paper, and
5 adjacent to each other, it is possible to effectively
reduce the possibility of being affected by the
unevenness in the tone introduced in the main scan
direction and/or the sub scan direction during the
developing process.

10 Therefore, this first embodiment of the
present invention is characterized in that the image
forming apparatus outputs an evaluation chart including
a first pattern group made up of first patterns which
are repeated in a sub scan direction with a period that
15 is an integer multiple of a number of light beams used
and are also repeated in a main scan direction at
predetermined intervals, and a second pattern group made
up of second patterns which are repeated in the sub scan
direction with a period which is an integer multiple of
20 the number of light beams used and are also repeated in
the main scan direction at predetermined intervals,
where each first pattern has, with respect to a row of
dots formed in the main scan direction by a
predetermined light beam, a row of dots formed by a next
25 light beam and shifted in the main scan direction, and

each second pattern has, with respect to a row of dots formed in the main scan direction by a predetermined light beam, a row of dots formed by a next light beam and shifted in the main scan direction but in a direction opposite to a shift direction of the first pattern. In addition, the evaluation chart is characterized in that, of a plurality of light beams ($B_1, B_2, \dots, B_m, B_m \geq 2$), the first and second pattern groups formed by the light beams B_1 and B_2 , the first and second pattern groups formed by the light beams B_2 and B_3, \dots , the first and second pattern groups formed by the light beams $B_{(m-1)}$ and B_m , and the first and second pattern groups formed by the light beams B_m and B_1 are printed on the same paper.

15 Second Embodiment:

 In a second embodiment of the image forming apparatus according to the present invention, the plurality of light beams emitted from the light source portion 61 are deflected by the polygon mirror 63 which forms the deflecting means and simultaneously scan the photoconductive body 66 in the main scan direction. This image forming apparatus is characterized in that an evaluation chart which will be described hereunder is output. The evaluation chart includes first patterns and second patterns. In the first pattern, with respect

to a row of dots formed in the main scan direction by one predetermined light beam, a row of dots formed by the next one light beam is shifted in the main scan direction. In the second pattern, with respect to the
5 row of dots formed in the main scan direction by one predetermined light beam, a row of dots formed by the next one light beam is shifted in the main scan direction but in a direction opposite to the shift direction of the first pattern. The evaluation chart
10 actually includes a first pattern group which is formed by the first patterns which are repeated in the sub scan direction with a period that is an integer multiple of the number of light beams, and a second pattern group which is formed by the second patterns which are
15 repeated in the sub scan direction with a period that is an integer multiple of the number of light beams.

FIG. 15 is a diagram for explaining the evaluation chart used in this second embodiment. As shown in FIG. 15, the first pattern group P12a and the
20 second pattern group P12b are not repeated in the main scan direction on the evaluation chart used in this second embodiment. In other words, the first and second pattern groups P12a and P12b are repeated in only the sub scan direction with the period which is an integer
25 multiple (integer is one in the case shown in FIG. 15)

of the number of light beams used (two light beams in the case shown in FIG. 15), in a sequence P12a, P12b, P12a,

As described above, if the phases of the two
5 adjacent light beams differ, the width of the toner image of the first pattern A and the width of the toner image of the second pattern B become different.

FIGS. 16 and 17 are diagrams for explaining the evaluation charts used in the second embodiment. In
10 the evaluation charts shown in FIGS. 16 and 17, the phases of the two adjacent light beams differ, and the widths of the toner images of the first and second patterns A and B differ. FIG. 16 shows the evaluation chart for a case where the first and second pattern
15 groups arranged in the sub scan direction are disposed at the scan start side of the scan range of the polygon mirror 63. On the other hand, FIG. 17 shows the evaluation chart for a case where the first and second pattern groups arranged in the sub scan direction are
20 disposed at the central portion of the scan range of the polygon mirror 63. By visually checking the evaluation chart shown in FIG. 16 or 17, it is possible to effectively detect the phase error between the light beams.

25 In the case of the evaluation chart shown in

FIG. 16 in which the first and second pattern groups are disposed at the scan start side of the scan range of the polygon mirror 63, it is possible to simply detect the phase error between the light beams without being
5 affected by an irregular rotation of the polygon mirror 63.

FIG. 18 is a diagram for explaining a dot position error caused by the irregular rotation of a polygon motor which rotates the polygon mirror 63. In
10 FIG. 18, 23 denotes the surface of the photoconductive body 66, 24 denote aligned dots, 25 denotes the sub scan direction, 26 denotes non-aligned dots, 27 denotes the main scan direction, S denotes the scan start side of the scan range of the polygon mirror 63, and E denotes
15 the scan end side of the scan range of the polygon mirror 63.

In FIG. 18, at the scan start side S, the dots become aligned as indicated by the aligned dots 24. However, due to causes such as the irregular rotation of
20 the polygon mirror, the dots may become non-aligned as indicated by the non-aligned dots 26 at the scan end side E. In this case, it is preferable to dispose the first and second pattern groups P12a and P12b at the scan start side of the scan range as shown in FIG. 16,
25 in order to accurately detect the phase error between

the adjacent light beams.

On the other hand, in a case where the irregular rotation of the polygon motor or the like are less likely to occur, it is preferable to dispose the first and second pattern groups P12a and P12b at the central portion of scan range as shown in FIG. 17, in order to accurately detect the phase error between the adjacent light beams.

In other words, as shown in FIG. 2, the light beams are corrected in the laser optical system, so that the laser beams are deflected by the polygon mirror 63 and scan the image forming region on the photoconductive body 66 through the $f\theta$ lens 64 and the toroidal lens 65 at the same speed. However, it is difficult to correct the light beams so that the scanning speeds become exactly the same. Consequently, a slight optical distortion is generated at the scan start side and the scan end side of the scan range in the main scan direction.

For this reason, when the first and second pattern groups P12a and P12b are disposed as shown in FIG. 17 at the central portion of the scan range, that is, the central portion of the image forming region where the optical distortion is small, it is possible to accurately detect the phase error between the adjacent

light beams without being affected by the optical distortion caused by a lens or the like.

In the first pattern A and the second pattern B described heretofore, it is assumed for the sake of convenience that the number of rows of dots formed by each of the light beams B1 and B2 and aligned in the main scan direction is two, as shown in FIGS. 3A and 3B, for example. However, the number of rows of dots formed by one light beam and aligned in the main scan direction is of course not limited to two, and three or more rows of dots may be formed by one light beam.

FIGS. 19A and 19B are diagrams for explaining a pattern for a case where the number of semiconductor lasers is two and the number of rows of dots formed by one light beam and aligned in the main scan direction is one. FIG. 19A shows the first pattern A, and FIG. 19B shows the second pattern B.

FIGS. 20A and 20B are diagrams for explaining a pattern for a case where the number of semiconductor lasers is four and the number of rows of dots formed by one light beam and aligned in the main scan direction is four. FIG. 20A shows the first pattern A, and FIG. 20B shows the second pattern B.

The present inventor tested various evaluation charts output by use of a 2-beam image forming apparatus

(electrophotography engine) having a write resolution of 600 dpi. Of the various evaluation charts output, it was found that the phase error between the two light beams can be detected most effectively by use of the evaluation chart having one row of dots in the main scan direction as shown in FIGS. 19A and 19B.

In addition, the present inventor tested various evaluation charts output by use of a 4-beam image forming apparatus (electrophotography engine) having a write resolution of 1200 dpi. Of the various evaluation charts output, it was found that the phase error between two light beams can be detected most effectively by use of the evaluation chart having four rows of dots in the main scan direction as shown in FIGS. 20A and 20B.

Therefore, the number of rows of dots formed by one light beam on the evaluation chart may be changed depending on the image forming apparatus used and the write resolution employed.

When outputting the evaluation chart, it is also possible to change the distance in the main scan direction between the row of dots formed in the main scan direction by one predetermined light beam and the row of dots formed in the main scan direction by the next one light beam. FIGS. 21A and 21B are diagrams for

explaining the first and second patterns A and B similar to those shown in FIGS. 3A and 3B, but for a case where, with respect to a row of dots formed by a first light beam B1, a row of dots formed by a second light beam B2 has a distance deviation Δ in the main scan direction, as compared to FIGS. 3A and 3B. Because the row of dots formed by the second light beam B2 has the distance deviation Δ in the main scan direction with respect to the row of dots formed by the first light beam B1, the width W12a of the toner image of the first pattern A and the width W12b of the toner image of the second pattern B become as shown in FIGS. 21A and 21B, and it becomes possible to detect the phase error between the first and second light beams B1 and B2 with a higher sensitivity compared to the case shown in FIGS. 10A and 10B described above.

For example, in the image forming apparatus (electrophotography engine) having a write resolution of 1200 dpi, one dot is small, and it is not possible to obtain a sufficient potential drop by the exposure of one dot. For this reason, it becomes more difficult to form the toner images of the first and second patterns A and B if the distance deviation Δ is provided in the main scan direction between the rows of dots because an overlap of the dots will decrease. If the phase error

exists in the main scan direction between the light beams, it is more difficult for the toner image to be formed if the distance deviation Δ increases as shown in FIG. 22B, and it is easier for the toner image to be
5 formed if the distance deviation Δ decreases as shown in FIG. 22A. FIGS. 22A and 22B are diagrams for explaining the phase error of the light beams in the main scan direction. Therefore, it is possible to detect the phase error between the light beams with a
10 high sensitivity by comparing the first and second patterns A and B shown in FIGS. 22A and 22B, that is, based on the difference between the first and second patterns A and B shown in FIGS. 22A and 22B.

The exposing position indicated by the
15 circular mark and the toner adhering region indicated by the approximately oval mark in FIGS. 3A and 3B or FIGS. 21A and 21B change depending on the resolution and the shape of the laser beam used. The shape of the laser beam refers to the cross sectional shape of the laser
20 beam or the shape of the laser beam spot formed on the surface of the photoconductive body 66. For this reason, it is important to appropriately set the number of dots and the distance deviation Δ .

Accordingly, because of the need to change the
25 number of dots and the distance deviation Δ depending

on the conditions such as the resolution, the shape of the laser beam, the developing condition (image forming condition) and the like, it is preferable to generate the evaluation chart by an electronic circuit in a case
5 where one image forming apparatus has the function of forming images in either one of two resolutions, and to enable the number of dots forming the row of dots and the distance deviation Δ to be changed.

FIG. 23 is a system block diagram showing a
10 structure of a circuit for generating the first pattern A shown in FIG. 21A. FIGS. 24A and 24B are timing charts for explaining an operation of the circuit shown in FIG. 23.

The circuit shown in FIG. 23 includes a pulse
15 generating circuit (Pulse1) 201, a pulse delay circuit (Pulse-D) 202, and a pulse generating circuit (Pulse2) 203. The pulse generating circuit 201 generates a pulse signal Video1 corresponding to the light beam B1 in response to a clock signal CLK, as shown in FIG. 24A.
20 The pulse delay circuit 202 is triggered in response to a falling edge of the pulse signal Video1, and outputs a pulse signal Δ only during a predetermined time Δ . The pulse generating circuit 203 generates a pulse signal Video2 corresponding to the light beam B2 in response to
25 the pulse signal Δ , as shown in FIG. 24A.

A pulse width of the pulse signal is adjustable by a control signal ContD which is supplied to the pulse delay circuit 202, and a pulse width of the pulse signal Video2 is adjustable by a control signal ContW which is supplied to the pulse generating circuit 203. In other words, the number of dots is adjustable by the control signal ContW, and the distance deviation Δ (interval Δ) is adjustable by the control signal ContD. Therefore, it is possible to effectively detect the phase error between the light beams by appropriately setting the control signals ContD and ContW depending on the image forming apparatus (electrophotography engine).

The second pattern B shown in FIG. 21B may be generated by a circuit similar to the circuit shown in FIG. 23. Alternatively, it is possible to use the circuit shown in FIG. 23 to generate the second pattern B, by switching the pulse signals Video1 and Video2 as shown in FIG. 24B, so that the pulse signal Video2 corresponds to the light beam B1 and the pulse signal Video1 corresponds to the light beam B2.

As will be described later, the evaluation chart, that is, the first and second pattern groups, may be generated by software. In this case, the image data used for generating the evaluation chart may be stored in a recording medium such as a floppy disk and a ROM,

and read from the recording medium when necessary.
Alternately, the image data used for generating the
evaluation chart may be generated by the video
controller 71. In this latter case, the video
5 controller 71 may be realized by a personal computer or
the like.

In a case where the image data used for
generating the evaluation chart is fixed, such as the
case where the image data used for generating the
10 evaluation chart is prestored in the floppy disk, ROM or
the like, it is impossible to control the number of rows
of dots as described above in conjunction with FIGS. 23,
24A and 24B. For this reason, when an attempt is made
to print the patterns such as those shown in FIGS. 19A
15 and 19B at 1200 dpi, it may not be possible to obtain a
sufficient tone. In this case, the bias circuit 114
shown in FIG. 1 may be adjusted to set the bias
(developing bias) to a high value only when checking the
phase error, so that the dots having a sufficient tone
20 are printed.

In other words, the conditions related to the
formation of the dots, such as the developing bias, need
to be changeable in the case where the image data used
for generating the evaluation chart is fixed, such as
25 the case where the image data used for generating the

evaluation chart is prestored in the floppy disk, ROM or the like.

FIG. 25 is a flow chart for explaining a bias setting process. In FIG. 25, a step S1 decides whether or not the image forming apparatus is to carry out a normal operation. If the normal operation is to be carried out and the decision result in the step S1 is YES, a step S2 sets a normal bias (standard bias), and the process ends. On the other hand, if the normal operation is not to be carried out, that is, the phase error is to be checked, and the decision result in the step S1 is NO, a step S3 sets a bias value which is higher than the normal bias (standard bias), and the process ends.

Therefore, the phase error among the light beams B1, B2, B3 and B4 can effectively be detected visually. By changing the timings of each of the light beams B1, B2, B3 and B4 manually by the operator, for example, it is possible to realize an image formation in which the four light beams B1, B2, B3 and B4 are aligned without an error. FIG. 26 is a diagram for explaining the image formation by the four light beams B1, B2, B3 and B3 which are aligned without the error.

For example, in the 4-beam optical system which emits the four light beams B1, B2, B3 and B4, the

light beams B1 and B2 are adjusted, the light beams B2 and B3 are then adjusted, and the light beams B3 and B4 are thereafter adjusted. Finally the adjustment ends after confirming that there is no phase error between
5 the light beams B4 and B1.

FIG. 27 is a system block diagram showing a circuit for generating phase synchronizing signals (hereinafter referred to as horizontal synchronizing signals) S1, S2, S3 and S4 which are used to synchronize
10 the phases of the light beams B1, B2, B3 and B4 when the 4-beam optical system which emits the four light beams B1, B2, B3 and B4 is used. The circuit shown in FIG. 27 includes the phase synchronizing signal generating means 70 which forms a phase synchronizing signal generating
15 means, and a delay setting circuit 71 which forms a phase correction amount setting means. The delay setting circuit 71 sets a phase correcting amount in the main scan direction with respect to each of the light beams B1, B2, B3 and B4. Based on the phase correcting
20 amounts set by the delay setting circuit 71, the phase synchronizing signal generating means 70 generates the horizontal synchronizing signals S1, S2, S3 and S4 with respect to the light beams B1, B2, B3 and B4.

Accordingly, when the light beams B1, B2, B3
25 and B4 pass the horizontal synchronizing sensor 69, the

light beam B1 (semiconductor laser 85) is turned ON and the light beams B2, B3 and B4 (semiconductor lasers 86, 87 and 88) are turned OFF. In addition, the phase synchronizing signal generating means 70 generates the
5 horizontal synchronizing signals S1, S2, S3 and S4 respectively corresponding to the light beams B1, B2, B3 and B4 based on a signal Sync which is output from the horizontal synchronizing sensor 69 when the light beam B1 is detected thereby. The image data is printed in
10 synchronism with the horizontal synchronizing signals S1, S2, S3 and S4.

As described above, it is possible to determine whether or not a phase error exists among the light beams B1, B2, B3 and B4 by visually checking the
15 evaluation chart having the first pattern groups P12a, P23a, P34a and P41a and the second pattern groups P12b, P23b, P34b and P41b as shown in FIG. 9 or 14. If the phase error exists, the operator sets the phase correcting amount in the delay setting circuit 71 shown
20 in FIG. 27, so as to correct the generation timings of the horizontal synchronizing signals S1, S2, S3 and S4, that is, to correct the phase error. For example, in a case where a phase error exists among the light beams B1, B2, B3 and B4 as shown in FIG. 28, time intervals t12,
25 t23 and t34 of the horizontal synchronizing signals S1,

S2, S3 and S4 are adjusted as shown in FIG. 29 to change the print timings of the dots in the main scan direction, so that the phase error among the light beams B1, B2, B3 and B4 is corrected. FIG. 28 is a diagram for

5 explaining the case where the phase error of the light beams exists, and FIG. 29 is a timing chart for explaining the adjustment of the time intervals t_{12} , t_{23} , and t_{34} of the horizontal synchronizing signals S1, S2, S3 and S4.

10 FIG. 30 is a timing chart for explaining a dot shift caused by the timing adjustment of the horizontal synchronizing signal. In FIG. 30, if the timing of the horizontal synchronizing signal S3 is shifted to the right as indicated by S3', the corresponding dot
15 generating position also shifts to the right in response to this shift. Therefore, by adjusting the timings of the horizontal synchronizing signals S1, S2, S3 and S4, it is possible to finely adjust the phases of the four light beams B1, B2, B3 and B4.

20 FIG. 31 is a flow chart for explaining a process of correcting the phase error of the light beams using the delay setting circuit 71 shown in FIG. 27. In FIG. 31, a step S11 outputs, that is, prints, the evaluation chart shown in FIG. 9 or 14 on the paper by
25 the image forming apparatus. In a step S12, the

operator visually checks the evaluation chart which is output, and decides whether or not the tones of the adjacent pattern groups are the same. If the decision result in the step S12 is NO, it is judged that a phase error exists among the light beams, and a step S13
5 adjusts and corrects the phase error of the light beams using the delay setting circuit 71 shown in FIG. 27. The process returns to the step S11 after the step S13, so as to output the evaluation chart with the corrected
10 phase error. On the other hand, the process ends if the decision result in the step S12 is YES.

FIG. 32 is a system block diagram showing a structure of the phase synchronizing signal generating means 70 shown in FIG. 27. The phase synchronizing
15 signal generating means 70 shown in FIG. 32 includes a plurality of delay lines and a plurality of selectors. The horizontal synchronizing signal S1 is generated from the signal Sync output from the horizontal synchronizing sensor 69. More particularly, the signal Sync is output
20 as the horizontal synchronizing signal S1. The horizontal synchronizing signal S1 is delayed in five steps by a delay line 301. At the time of the adjustment, a selector 302 selects one of the five delayed signals from the delay line 301 in response to a
25 selection signal SEL12, and outputs the selected delayed

signal as the horizontal synchronizing signal S2.

Another delay line and another selector are successively provided at a stage next to the selector 302 as shown in FIG. 32, and the illustration of the remaining part of

5 the phase synchronizing signal generating means 70 is omitted in FIG. 32, but the horizontal synchronizing signals S3 and S4 can be generated similarly to the horizontal synchronizing signals S1 and S2.

In addition, it is possible to output an
10 evaluation chart having a pattern group of a predetermined one of the plurality of light beams with a phase which is shifted in advance in the main scan direction, with respect to each of the first pattern group and the second pattern group described above. By
15 outputting such an evaluation chart, it becomes possible to simply obtain a phase correcting amount for correcting the phase error among the light beams.

FIGS. 33A, 33B, 34A, 34B, 35A and 35B are diagrams for explaining the first pattern A and the
20 second pattern B for a case where the phase of the light beam B2 in the main scan direction is shifted in advance. FIGS. 33A and 33B respectively show the first pattern A and the second pattern B for a case where the phase of the light beam B2 in the main scan direction is shifted
25 in advance to the left. FIGS. 34A and 34B respectively

show the first pattern A and the second pattern B for a case where the phase of the light beam B2 in the main scan direction is not shifted in advance. FIGS. 35A and 35B respectively show the first pattern A and the second
5 pattern B for a case where the phase of the light beam B2 in the main scan direction is shifted in advance to the right.

Pattern groups formed by the first pattern A and the second pattern B shown in FIGS. 33A and 33B will
10 be referred to as pattern groups P12a-1 and P12b-1. Pattern groups formed by the first pattern A and the second pattern B shown in FIGS. 34A and 34B will be referred to as pattern groups P12a+0 and P12b+0. Pattern groups formed by the first pattern A and the
15 second pattern B shown in FIGS. 35A and 35B will be referred to as pattern groups P12a+1 and P12b+1. FIG. 36 is a diagram showing another evaluation chart used in this second embodiment, where the pattern groups P12a-1, P12b-1, P12a+0, P12b+0, P12a+1 and P12b+1 are arranged
20 in the manner shown. The phase correcting amount for correcting the phase error among the light beams can simply be obtained by use of this evaluation chart. For example, if the light beam B2 is actually shifted by +1 with respect to the light beam B1, for example, the tone
25 difference between the pattern groups P12a-1 and P12b-1

is eliminated by printing the pattern groups P12a-1 and P12b-1 which are shifted by -1 in advance. In this case, the phase correcting amount can simply be obtained as being -1.

5 In the particular cases described above, the shifts of -1, 0 and +1, that is, three shifting steps, are employed for the sake of convenience. However, the number of shifting steps may of course be greater than three. For example, it is possible to form the patterns
10 by employing eight steps in the negative direction (left shift), eight steps in the positive direction (right shift) and a zero shift, that is, by employing a total of seventeen shifting steps.

When the evaluation chart shown in FIG. 36 is
15 output, the phase correcting amount can be obtained by visually checking the evaluation chart, and the phase error (phase synchronization error) of the light beams can be adjusted and corrected manually by the operator.

FIG. 37 is a flow chart for explaining a
20 process of manually adjusting the phase error. In a step S21 shown in FIG. 37, the operator compares the pattern group pairs P12a-x and P12b-x, ..., P12a+x and P12b+x of two light beams such as the light beams B1 and B2, for example, and checks which of the pattern group
25 pairs from -x to +x has the smallest tone difference.

In a step S22, the operator inputs from the operation panel 74 a number corresponding to the shifting step having the smallest tone difference. For example, if the smallest tone difference is detected for the shifting step -1, a number corresponding to this shifting step is input from the operation panel 74. The phase correcting amounts, that is, adjusting values, are prestored in a non-volatile memory such as a ROM 73 within the video controller 71 shown in FIG. 2. When the number corresponding to the shifting step -1 is input from the operation panel 74, the phase correcting amount (adjusting value) corresponding to this input number is read from the ROM 73 and supplied to the delay setting circuit 71 shown in FIG. 27. Hence, a step S23 corrects the phase error between the two light beams, namely, the light beams B1 and B2 in this particular case, using the read phase correcting amount (adjusting value). After the step S23, operations and processes similar to those described above with respect to the light beams B1 and B2 are carried out with respect to each of the other two light beams to correct the phase error.

Therefore, after the evaluation chart is output, the operator visually detects the tone difference of the patterns, and adjusts and corrects the

phase error by making the manual input from the operation panel 74. However, the image forming apparatus may be constructed to automatically adjust or correct the phase error.

5 FIG. 38 is a system block diagram showing a structure of an image forming apparatus which is provided with a function of automatically correcting or adjusting the phase error. The image forming apparatus shown in FIG. 38 includes a generating means 151, a tone
10 measuring means 152, a phase correcting amount setting means 153, and the phase synchronizing signal generating means 70. With respect to each of the first pattern group and the second pattern group, the generating means 151 generates on the photoconductive body 66 the pattern
15 group of a predetermined one of the plurality of light beams having the phase in the main scan direction shifted in advance. The tone measuring means 152 measures the tone of the pattern group on the photoconductive body 66. Based on the tone measured by
20 the tone measuring means 152, the phase correcting amount setting means 153 sets the phase correcting amount in the main scan direction. The phase synchronizing signal generating means 70 generates the horizontal synchronizing signals (phase synchronizing
25 signals) of the light beams based on the phase

correcting amount set by the phase correcting amount setting means 153. The tone measuring means 152 may be realized by a tone sensor, for example. Further, the phase correcting amount setting means 153 may be realized by the delay setting circuit 71 shown in FIG. 27, for example.

FIG. 39 is a diagram for explaining setting of the tone measuring means 152 which measures the tone of the pattern group on the photoconductive body 66. In FIG. 39, those parts which are the same as those corresponding parts in FIG. 2 are designated by the same reference numerals, and a description thereof will be omitted. A reference numeral 76 in FIG. 39 designates a phase synchronization control means. FIG. 40 is a diagram for explaining the pattern groups formed on the photoconductive body 66. In the case shown in FIG. 39, the pattern groups shown in FIG. 40 are formed on the photoconductive body 66, and a tone sensor 761 is set to measure the tone of the left pattern groups, while a tone sensor 763 is set to measure the tone of the right pattern groups.

In the image forming apparatus shown in FIGS. 38 and 39, the tones of the pattern groups on the photoconductive body 66 are measured by the tone sensors 761 and 763. Hence, it is possible to automatically

adjust or correct the phase error of the light beams without the need to actually print the image of the evaluation chart on the paper.

FIG. 41 is a flow chart for explaining an automatic adjusting or correcting process for adjusting or correcting the phase error of the light beams in the image forming apparatus shown in FIGS. 38 and 39.

In FIG. 41, a step S31 exposes the pattern groups shown in FIG. 40 on the photoconductive body 66, and a step S32 measures the tones of the pattern groups formed on the photoconductive body 66 by the tone sensors 761 and 763. Then, a step S33 detects the pair of pattern groups having the same tone. In other words, of the pattern groups shown in FIG. 40, the tones of the left pattern groups are measured by the tone sensor 761, the tones of the right pattern groups are measured by the tone sensor 763, and a decision is made to determine whether the tone of one of the left pattern groups matches the tone of one of the right pattern groups, so as to detect the pair of left and right pattern groups having the same tone. For example, with respect to the light beams B1 and B2, the pair of pattern groups P12a+1 and P12b+1 are detected as having the same tone. When the pair of pattern groups P12a+1 and P12b+1 are detected as having the same tone, a step S34 sets the

corresponding phase correcting amount -1 in the delay setting circuit 71. In other words, since the light beam B2 is shifted by +1 with respect to the light beam B1, the correcting amount -1 is set. As a result, the phase synchronizing signal generating means 70 automatically corrects the phase error between the two light beams B1 and B2. The phase synchronizing signal generating means 70 automatically corrects the phase error between the next two light beams B2 and B2 in a similar manner, and the phase error between two light beams can be corrected automatically for the other light beams.

According to the image forming apparatus shown in FIGS. 38 and 39, it is possible to detect the phase error between the light beams within the image forming region in a simple manner and with a high sensitivity. In addition, the phase error of the light beams can be corrected automatically, thereby requiring no manual correcting operation. As a result, it is possible to reduce the burden on the operator, including service or maintenance personnel and users.

The video controller 71 of the image forming apparatus according to the present invention may be formed by an electronic circuit or, by a personal computer or the like. FIG. 42 is a system block diagram

showing a hardware structure of the video controller 71 within the image forming apparatus. The image forming apparatus is formed by a personal computer or the like in the case shown in FIG. 42, and the video controller 5 71 includes a CPU 41, a ROM 73, a RAM 43, and a hard disk drive (HDD) 44 including at least one hard disk. The CPU 41 controls the general operation of the image forming apparatus. The ROM 73 stores control programs and the like to be executed by the CPU 41. The RAM 43 10 is used as a work area for the CPU 41. The hard disk drive 44 is used to store various data, and may also be used as the work area for the CPU 41.

The CPU 41 includes a function of carrying out the process of the image forming apparatus according to 15 the present invention described above. More particularly, the CPU 41 includes the function of carrying out the process to output the evaluation chart which includes first patterns and second patterns. In the first pattern, with respect to a row of dots formed 20 in the main scan direction by one predetermined light beam, a row of dots formed by the next one light beam is shifted in the main scan direction. In the second pattern, with respect to the row of dots formed in the main scan direction by one predetermined light beam, a 25 row of dots formed by the next one light beam is shifted

in the main scan direction but in a direction opposite to the shift direction of the first pattern. The evaluation chart actually includes a first pattern group which is formed by the first patterns which are repeated
5 in the sub scan direction with a period that is an integer multiple of the number of light beams and are also repeated in the main scan direction at predetermined intervals, and a second pattern group which is formed by the second patterns which are
10 repeated in the sub scan direction with a period that is an integer multiple of the number of light beams and are also repeated in the main scan direction at predetermined intervals.

Alternatively, the CPU 41 includes the
15 function of carrying out the process to output the evaluation chart which includes first patterns and second patterns. In the first pattern, with respect to the row of dots formed in the main scan direction by one predetermined light beam, the row of dots formed by the
20 next one light beam is shifted in the main scan direction. In the second pattern, with respect to the row of dots formed in the main scan direction by one predetermined light beam, the row of dots formed by the next one light beam is shifted in the main scan
25 direction but in a direction opposite to the shift

direction of the first pattern. The evaluation chart actually includes a first pattern group which is formed by the first patterns which are repeated in the sub scan direction with a period that is an integer multiple of the number of light beams, and a second pattern group
5 which is formed by the second patterns which are repeated in the sub scan direction with a period that is an integer multiple of the number of light beams.

The above described function of the CPU 41 may
10 be provided in the form of a software package, by a recording medium such as a CD-ROM. Hence, in the case shown in FIG. 42, a medium driver 31 is provided to drive a recording medium 30 when the recording medium 30 is set in the image forming apparatus. This recording
15 medium 30, which may be any kind of recording media capable of storing a computer program, forms a computer-readable storage medium according to the present invention.

Therefore, the video controller 71 or, the
20 image forming apparatus which includes the video controller 71, may be realized by a microprocessor of a general purpose computer system which executes a computer program for causing the computer system to carry out the above described process of the image
25 forming apparatus according to the present invention.

This computer program may be stored in the recording medium 30 such as the CD-ROM, and in this case, the computer program read from the recording medium 30 is installed into the computer system by being written into the hard disk of the hard disk drive 44, for example.

As described above, the recording medium 30 which stores the computer program may be formed by any kind of recording media capable of storing the computer program, such as ROM, RAM, flexible disk, memory card, optical disk and magneto-optical disk, and is not limited to the CD-ROM. In addition, a storage unit of the computer system to which the installed computer program is written is of course not limited to the hard disk.

Further, the present invention is not limited to these embodiments, but various variations and modifications may be made without departing from the scope of the present invention.

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